Climate Change – The Globe Down to the Southwest

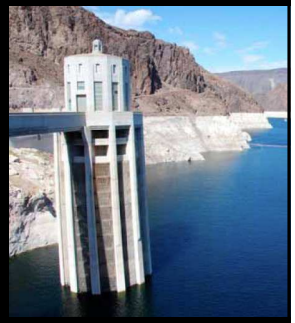
Jonathan Overpeck, The University of Arizona

Outline of talk:

(1) Climate in the news - 2011

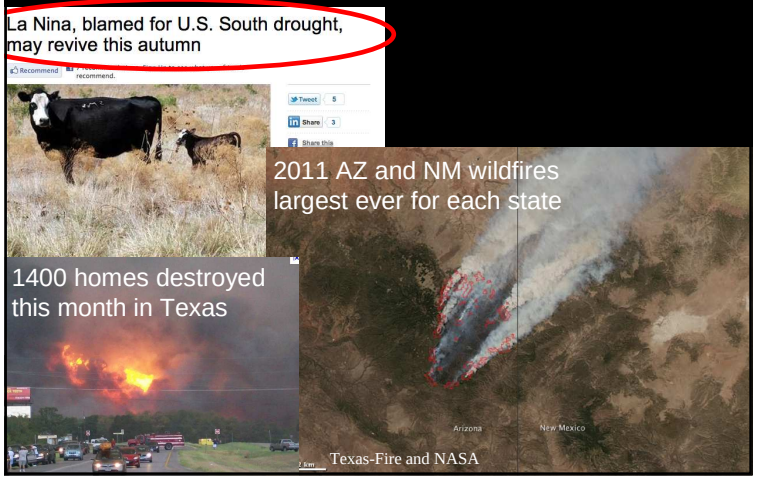
(2) Global climate change

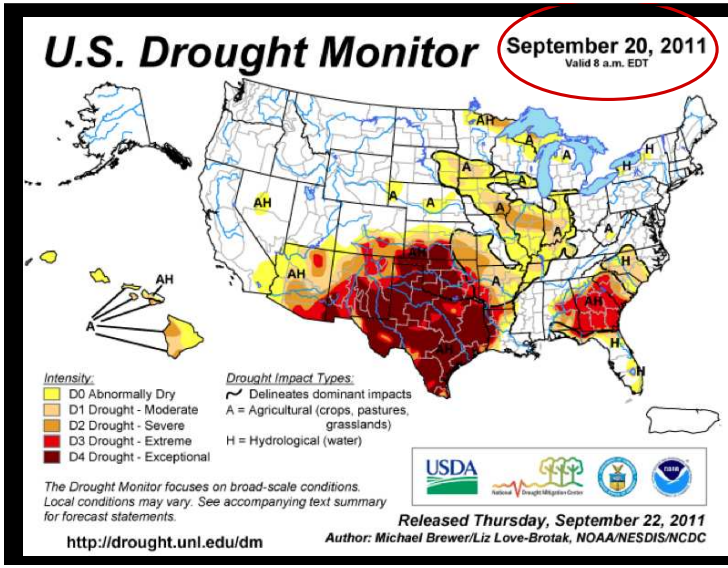
(3) ***Implications for Arizona and the Southwest***

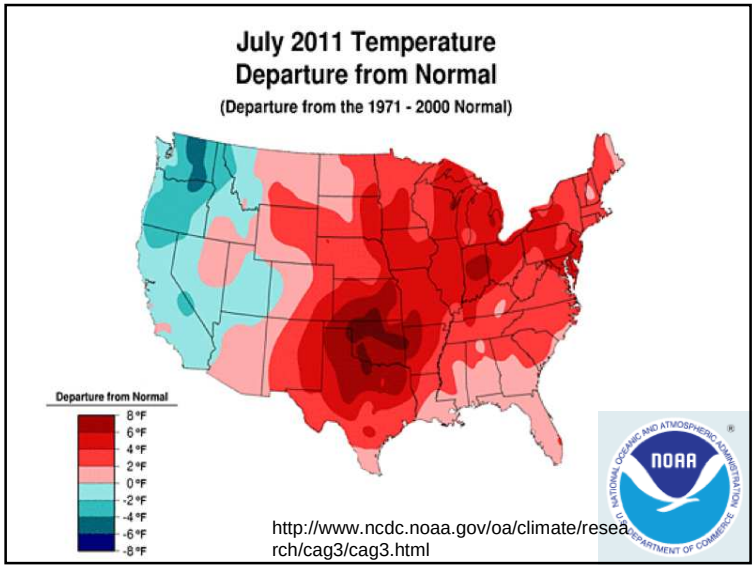


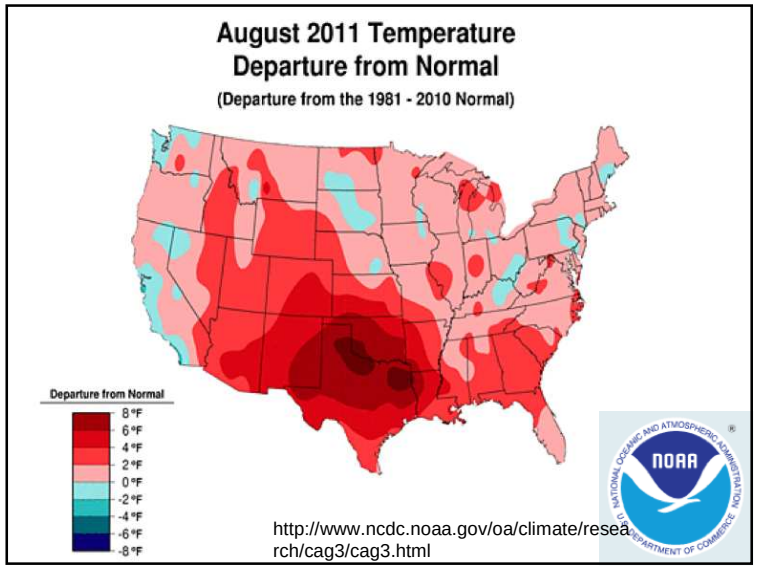
Source: Phil Pasteris, Global Water Resources. April 16, 2009

Climate in the news 2011…
Drought and Wildfire









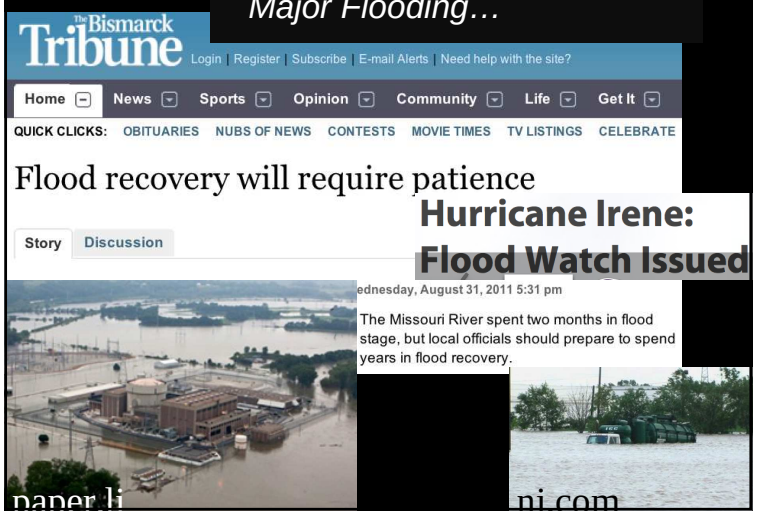
http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html

Climate in the news 2011…
Unusually deadly tornadoes

http://drpinna.com

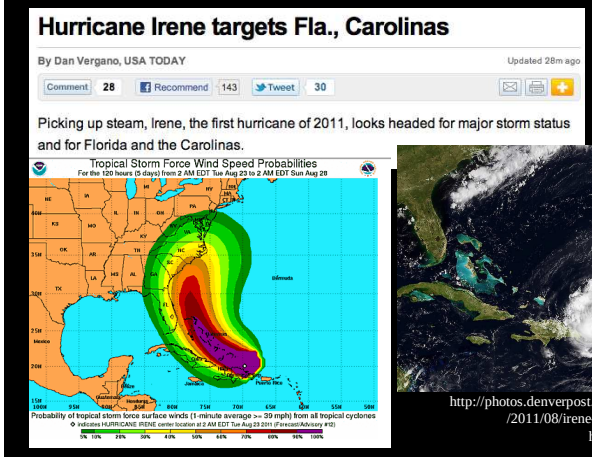
The Joplin tornado is the deadliest single tornado since modern recordkeeping began in 1950 and is ranked as the 7th deadliest in U.S. history

Climate in the news 2011…
Major Flooding…



paper.li ni.com

Climate in the news 2011…
Hurricanes delivering more moisture



http://photos.denverpost.com/mediacenter/2011/08/irene-the-first-atlantic-hurricane-of-2011

Climate in the news 2011…

Heat Waves…

guardian.co.uk

News | Sport | Comment | Culture | Business | Money | Life & style

News › World news › United States

Heatwave sweeps US claiming 22 lives

National weather service warns people to stay indoors and electricity companies warn of power outages

Record number of days above 110°F in Phoenix

PINAL COUNTY

Type Size: A A A Print Email Most Popular SHARE

Pinal utility cuts off customers amid August heat wave

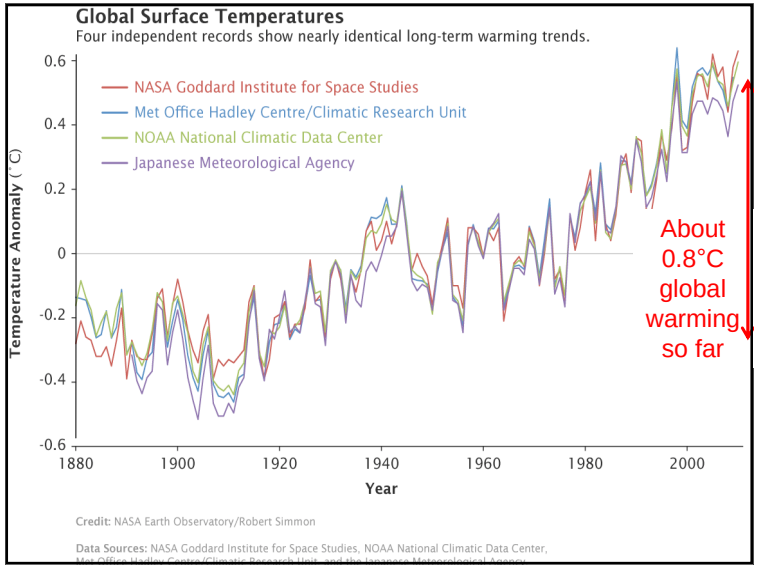
by Lindsey Collom - Sept. 2, 2011 10:00 AM
The Arizona Republic

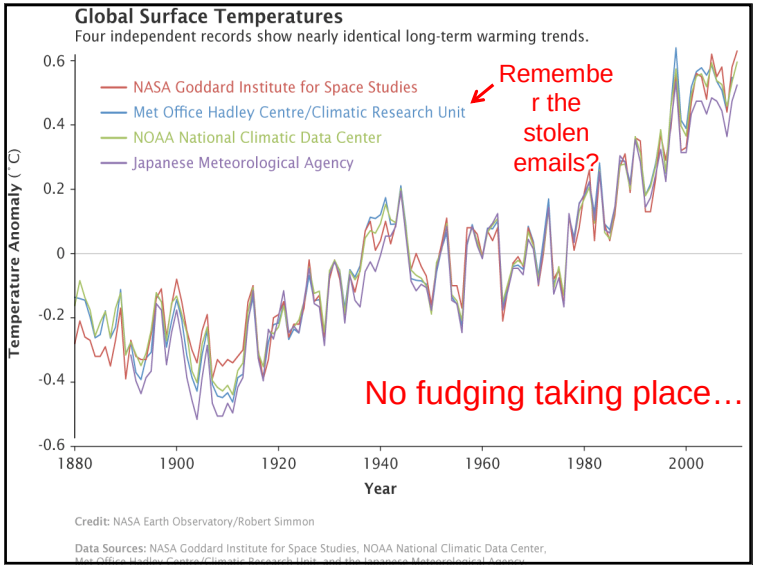
108°F in New Jersey!!

Heatwave breaks records in parts of US and Canada

What's going on?

Global Warming?
Climate Change?
Natural Variability?





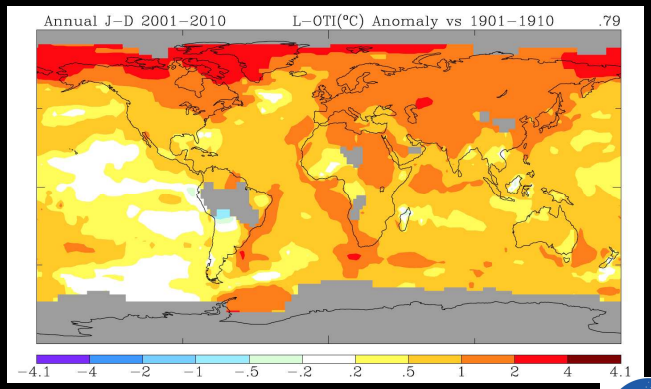
The climate challenge includes…

…both climate variability and climate change

…both natural and human-caused change (warming trend is ca. 90% human, 10% natural

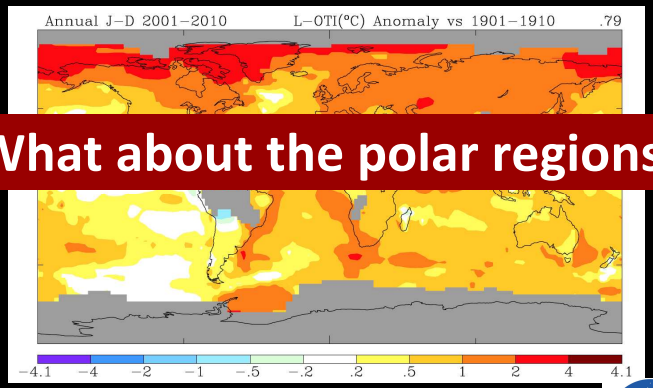
…change that is already clearly underway

The Earth has warmed almost everywhere - very likely (90% sure) mostly due to humans



Temperature change between decade 1901-1910 and decade 2001-2010 (**°C**)

The Earth has warmed almost everywhere - very likely (90% sure) mostly due to humans

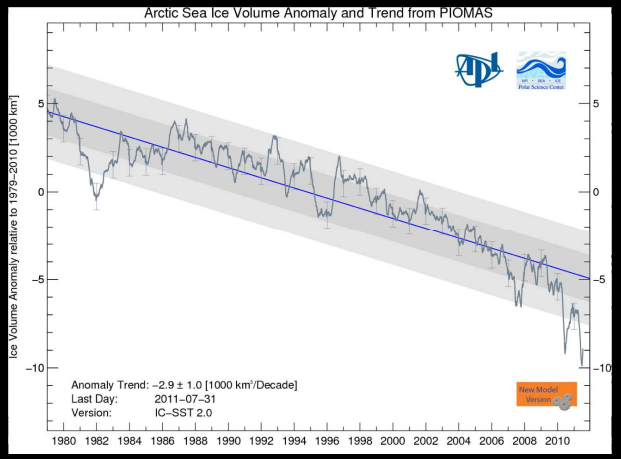


What about the polar regions?

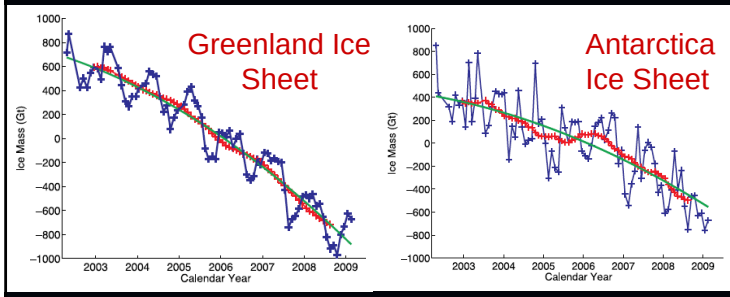
Temperature change between decade 1901-1910 and decade 2001-2010 (**°C**)

The Volume (Area x Thickness) of Sea Ice in the Arctic has been plummeting

Ice Volume Change



Accelerating Ice Sheet Mass Loss



- Graphs show *relative* changes in ice mass
- Ice mass is decreasing in both hemispheres
  - 1500 Gt from Greenland, 800 from Antarctica = 2300 Gt ice
  - About 7 mm of global sea level rise in 7 years (ca. 30% of total)
- Rate of mass loss has doubled: melt is *accelerating*
- Data from GRACE satellite project (gravity data) - *Velicogna 2009, GRL*

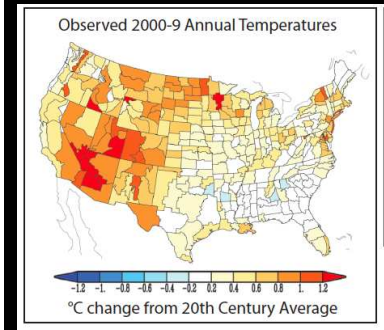
Turning to climate change… *IPCC, 2007*

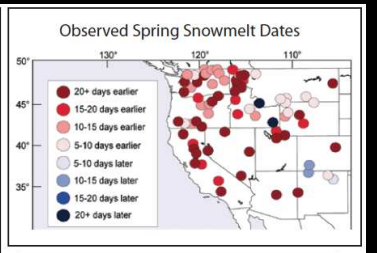
"Global Warming is *unequivocal*"

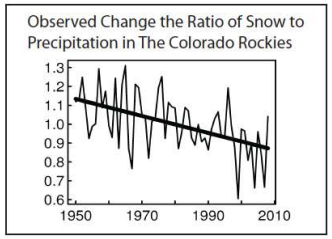
Since 1970, rise in:
- Global surface temperatures
- Extreme high temperatures
- Heat waves
- Lower atmosphere temperatures
- Global sea-surface temperatures
- Ocean heat content
- Water vapor
- Rainfall intensity
- Drought
- Hurricane intensity
- Global sea level/coastal flooding

Decrease in:
- NH Snow extent
- Arctic sea ice
- Glaciers
- Cold temperatures

Evidence of climate change in West clear…







(sources: NOAA; USGS, 2005; updated from Pierce et al., 2008)

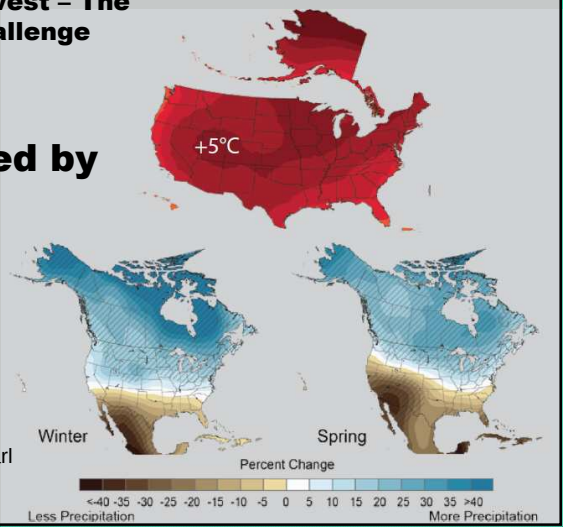
U.S. Southwest – Major Climate-related **Water** Impacts Underway

Bleached rock indicating a former high-water mark on outcroppings surrounding Lake Mead.

(Source: *New York Times*, October, 2010)

U.S. Southwest – The Climate Challenge

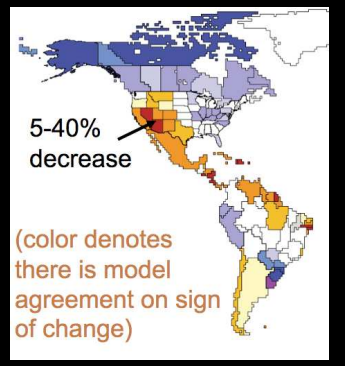
Change Projected by 2100



(source: From Karl et al., 2009)

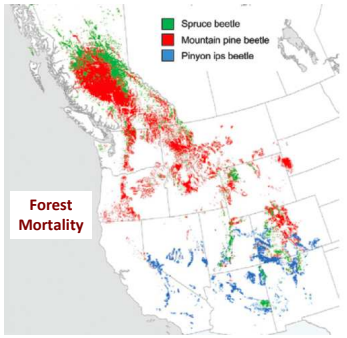
…even **by mid-century**, *and with modest reductions in carbon dioxide emissions*, the **Colorado River flow will likely decrease**

- **Published estimates ALL indicate there will be less water flowing in the Colorado**
- **Best estimate - *10 to 20% less average flow by 2050***
- ***Implies that there is a 30% chance that ALL Colorado River Basin storage could go dry by 2050 (Rajagopalan et al., 2009)***

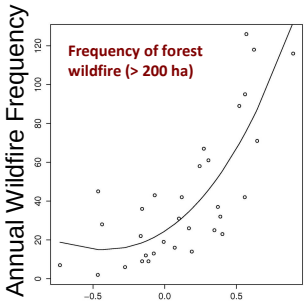


Base figure from Milly et al., 2008

U.S. Southwest – Major Climate-induced **Ecosystem** Impacts Underway

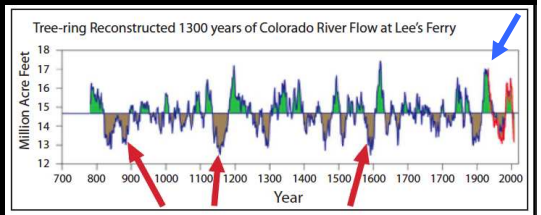


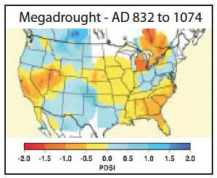
(Source: Raffa *et al.*, 2008; Westerling *et al.*, 2006)



U.S. Southwest – The climate challenge

Decades-long "Megadrought" occurs regularly





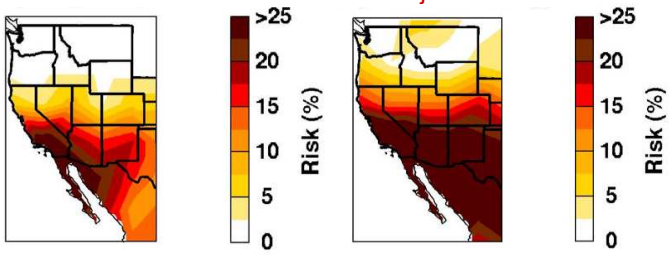
(Sources: Meko *et al.*, 2007; Karl *et al.*, 2009; Cook *et al.*, 2010; photo by J. Overpeck)

Emerging issue…

Risk of a Multi-decade "megadrought" in the 21st century likely higher than currently thought

Unadjusted Model Projections

NEW Proxy-based Rescaling of Model Projections



Source: Ault et al., *PNAS* (in review)

Summary Betting Guide for Climate Change in Arizona

More greenhouse gas emissions means…

Warmer – sure bet (happening already)

Less snow – excellent odds (happening)

Drier soils – excellent odds (happening)

Less late winter snow/rain – good odds (happening)

Less water in rivers – esp. Colorado River – good odds (already happening)

More intense rain and more flooding – good odds

More frequent/severe drought - good odds

Hotter drought - excellent odds (happening)

The climate challenge is clearly a tough one for the Arizona and the Southwest… ground zero for climate change in the U.S.

But is the news all bad?

The climate challenge also includes opportunities, particularly with respect to:

- **adaptation capability** (e.g., no-regrets adaption to hot drought)
- efficiency and **renewable energy**, solving the climate challenge also means **cleaner air** and a major **economic advantage for Arizona**
- **avoiding conflicts and crisis over water supply**

Photo: J. Overpeck

2010 - record global temperatures during near-record solar minimum – another confirmation that changes in the sun are not driving global warming